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(54) Abstract Title

Add/drop multiplexer

(57) An add/drop multiplexer couples trunk 1, 2, 11, 12 and branch 3, 13, fibres in a wavelength division multiplexed optical network. It selectively feeds particular carrier wavelengths λ_1, λ_2 from the trunk inputs 1, 2 to the trunk and branch outputs 11, 12, 13, and from the branch input 3 to the trunk outputs 11, 12. Signals are selected by, for example, fibre Bragg gratings 31, 32, acting as reflecting filters, and routed via circulators 21, 22, 23. During such routing the signals may be amplified by bidirectional doped fibre amplifiers 41, 42, which are pumped at 50.

The arrangement comprises a linear 'chain' of circulators 21, 23, 22 with 3 port circulators at both ends of the chain and one or more 3 or 4 port circulators forming the middle of the chain.

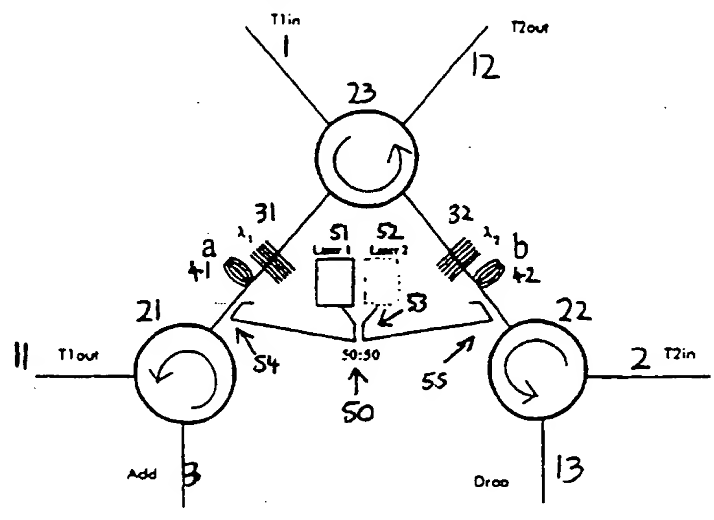

Fig. 1

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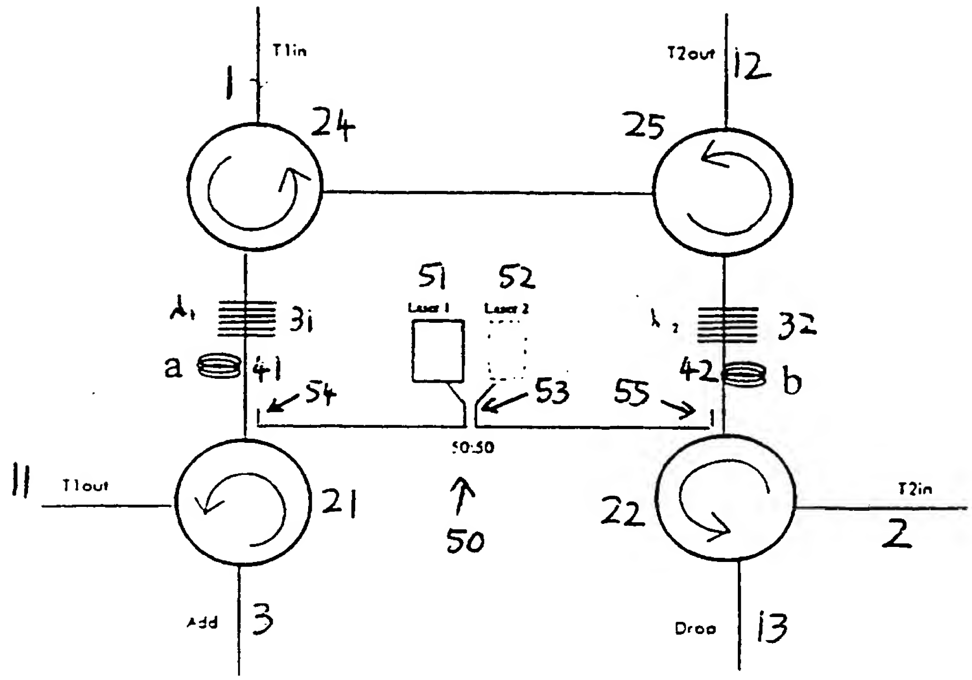
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41
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T1out
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Add
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Drop
13

Fig. 2

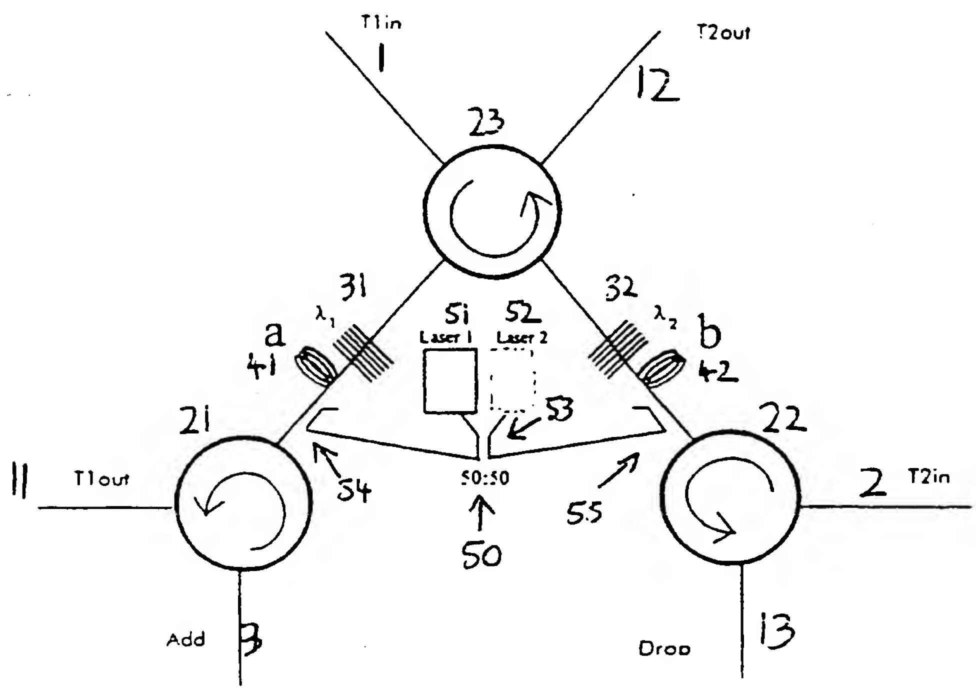
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Fig. 1

ADD/DROP MULTIPLEXER

The present invention relates to an add/drop multiplexer for use in a wavelength division multiplexed optical network, and to a branching unit comprising such an add/drop multiplexer.

Wavelength division multiplexing, termed WDM, (discussed in, for example, Spirit and O'Mahony, "High Capacity Optical Transmission Explained", John Wiley & Sons, Chichester, 1995, and Hill, British Telecom Technology Journal, 6 (3):24-31) is a technique of considerable benefit in optimising transmission of signals through fibre optic networks. In wavelength division multiplexing, traffic signals to be sent out by a station of the network are modulated on to a number of carrier signals at different predetermined carrier wavelengths. Each predetermined carrier wavelength is allocated according to the identities of the send station and of the intended receive station. Predetermined carrier wavelengths are spaced sufficiently far apart in wavelength that they can be discriminated from each other by components of the fibre optic system, but in many networks will also need to be grouped sufficiently closely that different (often all) carrier wavelengths can be amplified satisfactorily by the same amplifier in a repeater. The carrying capacity of a single fibre is enhanced by WDM - rather than carrying a single signal, the fibre is simultaneously carrying several signals, each at a different carrier wavelength.

Most such transmission networks have a number of nodes at which one or more branches separate from a main trunk or ring. Typically, at these nodes one or more carrier wavelengths are dropped down one or more fibres of the branch and one or more carrier wavelengths (which may be the same as, or different from, those dropped from the trunk or ring) are added to the trunk or ring from another fibre of the branch. The component of

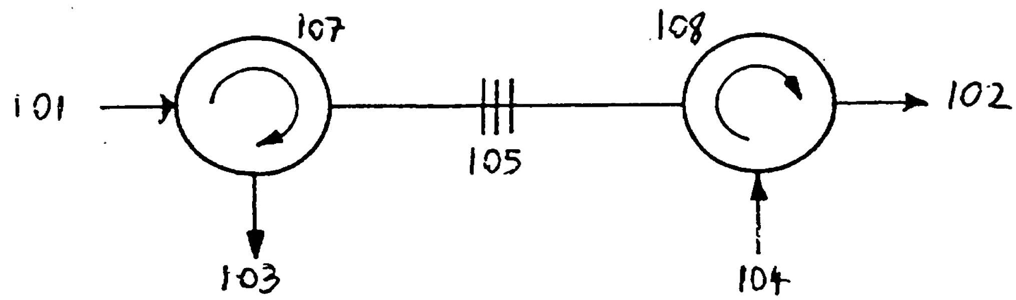

FIG. 3.

which performs such a function is an add/drop multiplexer (ADM).

WDM is particularly well adapted to efficient routing of signals between send and receive stations. As different signals have different carrier wavelengths, optical components can be used to route signals appropriately by directing them according to the carrier wavelength of the signal. Example of an ADM of this type is disclosed in Giles and Mizrahi IOOC 95, ThC2-1 pp 66-67. This add/drop multiplexer comprises two three port circulators (107,108) with a fibre Bragg grating (105) between the second ports of the circulators (Figure 3). The input of a first fibre (101) is connected to the first port of first circulator (107) and the output of the first fibre (102) is connected to the third port of the second circulator (108). A second fibre input (104) is connected to the first port of the second circulator (108) and a second output fibre (103) is connected to the third port of the first circulator (107). The two second ports are connected to each other with the fibre Bragg grating (105) therebetween. The reflection wavelength of the fibre Bragg grating is the wavelength to be added or dropped. Signals at any other wavelength enter the first port of the first circulator (107), pass through to the second port of the first circulator (107) and through the grating into the second port of the second circulator (108), then out of the first output (102). Signals at the fibre Bragg grating reflection wavelength arriving on the first fibre pass through from the first port to second port of the first circulator (107), are then reflected by the fibre Bragg grating (105) back to the second port of the first circulator (107), where they are circulated to the third port of the first circulator (107) and to the second output (103). By contrast, signals added at this wavelength on the second fibre input (104) pass from first to second port of the second circulator (108), whereafter they are reflected by the fibre Bragg grating (105) back to the second port of the second circulator (108), and are circulated out to the third port of the second circulator (108) and out onto the first (102)

output.

In wavelength division multiplexed systems of significant length, it will be necessary to amplify the traffic signals. A particularly appropriate point to amplify the traffic signals is at a branching unit, because the routing of traffic signals through the add/drop multiplexer will be accompanied by loss of power. Chawki et al, "Evaluation of an Optical Boosted Add/Drop Multiplexer OBADM including circulators and fiber grating filters", Proc. 21st Eur. Conf. on Opt. Comm. (ECOC"95 - Brussels), discloses an add/drop multiplexer of this type incorporating a bidirectional amplifier. The bidirectional amplifier is located between the first three port circulator and the fibre Bragg grating. With the configuration described above, the bidirectional amplifier will amplify all signals remaining on the trunk (from first inp;ut to first output) together with the signal dropped from the trunk to the branch (second output). The add signal (first input) will, however, not be amplified. In an alternative arrangement, instead of the fibre Bragg grating reflecting the add/drop wavelength or wavelengths, fibre Bragg gratings are provided to reflect all the traffic signal wavelengths for onward transmission along the trunk. In this case, the third port of the first circulator is connected to the trunk output and third port of the second circulator is connected to the branch drop output. In this case, all wavelengths will be amplified, the traffic signal remaining on the trunk being amplified twice and the add and the drop signals being amplified once.

Although these arrangements are useful, it is particularly desirable to simplify the ADM design to minimise the number of optical components, while obtaining low losses and a controllable and balanced system response. A particular difficulty arises when there are a plurality of fibres on the trunk. It is particularly desirable to handle effectively the adding or dropping of signals from a branch station to a trunk with such a plurality of fibres.

Accordingly, an earlier application of the present applicants, International Patent Application No. PCT/GB96/01891, discloses a plurality of arrangements in which an ADM combines traffic signals dropped from a plurality of trunk fibres onto a single spur drop fibre and splits from a single spur add fibre a plurality of add signals for adding to different fibres of the trunk. Such arrangements allow for minimisation of the number of optical components required and for effective balancing of losses. However, these designs do not themselves provide for efficient amplification of the traffic signals.

Accordingly, the invention provides an add/drop multiplexer for use in a wavelength division multiplexed optical network, the add/drop multiplexer having a first trunk input for receiving traffic signals from a first part of a first trunk fibre, a second trunk input for receiving traffic signals from a first part of a second trunk fibre, a first trunk output for outputting traffic signals to a second part of the first trunk fibre, a second trunk output for outputting traffic signals to a second part of the second trunk fibre, a branch input for receiving traffic signals from a branch input fibre, and a branch output for outputting traffic signals to a branch output fibre;

the add/drop multiplexer comprising:

means of routing from the first trunk input to the branch output a first set of traffic signals at carrier wavelengths predetermined for transmission of signals from the first trunk fibre to a branch station and for routing from the second trunk input to the branch output a second set of traffic signals at carrier wavelengths predetermined for transmission of signals from the second trunk fibre to the branch station, and means for combining said first and second sets

of traffic signals for output at the branch output;

means for separating traffic signals received at the branch input into a third set of traffic signals at carrier wavelengths predetermined for transmission of signals from the branch station to the first trunk fibre and a fourth set of traffic signals at carrier wavelengths predetermined for transmission of signals from the branch station to the second trunk fibre, and means for routing the third set of traffic signals to the first trunk output and the fourth set of traffic signals to the second trunk output respectively; and

one or more amplifiers located on traffic signal paths determined by said routing means, such that said one or more amplifiers amplify each routing for traffic signals determined by said routing means and each of said one or more amplifiers is adapted to amplify traffic signals for a plurality of said routings.

Preferably, the amplifiers are bidirectional, in which case at least one of the amplifiers can support traffic signal routings which are arranged to pass through that amplifier in opposite directions. Particularly appropriate are doped fibre amplifiers, in which case the add/drop multiplexer also comprises a pumping section for pumping the doped fibre amplifier. The pumping section comprise a first laser and a fibre optic coupler, wherein the output of the first laser is split into two output paths by the fibre optic coupler. A further advantageous arrangement provides redundancy by the addition of a second laser connected to the same side of the fibre optic coupler as the first laser so that light provided on each of these two output paths is a combination of light provides by the first laser and light provide

by the second.

In preferred arrangements, the add/drop multiplexer comprises a plurality of optical circulators and a plurality of notch reflector filters, preferably fibre Bragg gratings. In preferred arrangements, the plurality of optical circulators forms a linear chain, and the first and last circulators of the chain are three port circulators. It is advantageous that a first set of notch reflection filters is then provided between the first and second circulator to reflect signals to first set of one or more traffic signal wavelengths and a second set of notch reflection filters is provided between the penultimate and the last circulator to reflect signals at a second set of one or more traffic signal wavelengths. In a particularly preferred arrangement, at least two amplifiers are provided, wherein one of the two amplifiers is located between the first circulator and the first set of notch reflection filters and the other of two amplifiers is located between the second set of reflection filters and the last circulator. Advantageously in this arrangement, the pumping section has at least two outputs, one of the two outputs is coupled to the linear chain adjacent to these two amplifiers and the second of the two outputs is coupled to the linear chain adjacent to the second of the two amplifiers.

In a further aspect, the invention provides an add/drop multiplexer for use in a wavelength division multiplexed optical network, the add/drop multiplexer having a plurality of inputs each for receiving traffic signals from a different fibre of the network and a plurality of outputs each for outputting traffic signals to a different fibre of the network, wherein the add/drop multiplexer comprises a plurality of optical circulators and a plurality of notch reflection filters wherein:

the plurality of optical circulators form a linear chain;

the first and last circulators in the chain are three port circulators, wherein the first port of each of the first and last circulators is connected to a different input of the add/drop multiplexer, and wherein the third port of each of the first and last circulators is connected to a different output of the add/drop multiplexer, wherein the second port of each of the first and last circulators is connected to the adjacent circulator in the linear chain; and

one or more further circulators in the linear chain are four port circulators, wherein a first port of each of said further circulators is connected to a different input of the add/drop multiplexer, a fourth port of each of said further circulators is connected to a different output of the add/drop multiplexer, and the second and third ports of each of said further circulators are connected to adjacent circulators in said linear chain.

Specific embodiments of the invention are described in detail below, by way of example, with reference to the accompanying drawings, of which:

FIG 1 shows the first embodiment of an add/drop multiplexer according to the invention;

FIG 2 shows a second embodiment of an add/drop multiplexer according to the invention; and

FIG 3 shows a prior art add/drop multiplexer.

FIG 1 shows a first embodiment of an add/drop multiplexer according to the invention for use in a wavelength division multiplexed optical network. The add/drop multiplexer has a first trunk input (1) for receiving traffic signals from a first part of a first trunk fibre, a second trunk input (2) for receiving traffic signals from a first part of a second trunk fibre,

a first trunk output (11) for outputting traffic signals to a second part of the first trunk fibre and a second trunk output (12) for outputting traffic signals to a second part of the second trunk fibre. The add/drop multiplexer also has a branch input (3) for receiving traffic signals from a branch input, or add, fibre, and a branch output (13) for outputting traffic signals to a branch output, or drop, fibre.

The add/drop multiplexer comprises means for routing from the first trunk input (1) to the branch output (13) of the first set of traffic signals at carrier wavelengths predetermined transmission of signals from the first trunk fibre to a branch station and for routing from the second trunk input (2) to the branch output (13) a second set of traffic signals and carrier wavelengths predetermined for transmission of signals from the second trunk fibre to the branch station, and means for combining said first and second sets of traffic signals for output at the branch output (13).

In this embodiment, these routing means comprise three optical circulators (21,22,23) and two sets of fibre Bragg gratings (31,32). In this case there is one fibre Bragg grating in each set, the first fibre Bragg grating (31) reflecting signals at wavelength λ_1 and the second fibre Bragg grating (32) reflects signals at wavelength λ_2. The first fibre Bragg grating (31) is located between the second port of first circulator (21), which is a three port circulator, and the second port of the second circulator (23), which is a four port circulator. The second fibre Bragg grating (32) is located between the third port of the second circulator (23) and the second port of the third, and last, circulator (22), which is a three port circulator. The signals routed from the first trunk input (1) to the branch output (13) are at wavelength λ_1, the wavelength reflected by the first fibre Bragg grating. The signals enter on fibre (1) at the first port of the four port circulator (23), are circulated to the second port and pass out to the first fibre Bragg grating (31), where they are reflected. These signals

thus reenter the second port of the four port circulator (23) and pass out to the third port of the four port circulator (23). The signals then pass through the second fibre Bragg grating (32) to the second port of the last circulator (22) and out of the third port of the first circulator (22) to branch output fibre (13). Similarly, traffic signals at wavelength λ_2 are dropped from the second trunk input (2). These signals enter the first port of the last circulator (22), pass out of the second port of that circulator (22) and are reflected by the second fibre Bragg grating (32) back to the second port of the last circulator (22). The signal is then circulated to the third port of the last circulator (22) and out on to the branch output fibre (13). The circulator arrangement thus routes signals at these wavelengths from the respective trunk inputs and combines them for dropping at the branch output fibre (13).

The add/drop multiplexer also has means for separating traffic signals received at the branch input (3) into a third set of traffic signals at carrier wavelength predetermined for transmission of signals from the branch station to the first trunk fibre and a fourth set of traffic signals at a carrier wavelength predetermined for transmission of signals from the branch station to the second trunk fibre and means for routing the third set of traffic signals to the first trunk output (11) and the fourth set of traffic signals to the second trunk output (12) respectively.

Accordingly, traffic signals are provided at branch input (3) at carrier wavelength λ_1 for routing to the first trunk output (11) and λ_2 for routing to the second trunk output (12). These signals enter at the first port of the first circulator (21). The signals at λ_1 pass out of the second port of the first circulator (21) but are reflected at the first fibre Bragg grating (31). The signals thus pass back to the input of the first circulator (21) and out through the third port of the circulator (21) to the first trunk output (11). Signals at λ_2 by contrast, pass through the first fibre Bragg grating (31) to the second port of the four port circulator (23).

Signals are thus circulated out to the third port of the four port circulator (23) and pass out to the second fibre Bragg grating (32), where they are reflected. The signals thus pass back to the third port of the four port circulator (23) and out through the fourth port onto the second trunk output (12).

The add/drop multiplexer also comprises one or more amplifiers located on traffic signal paths determined by these routing means, such that the amplifiers between them amplify each routing for traffic signals determined by the routing means and whereby each of the amplifiers is adapted to amplify traffic signals for a plurality of routings.

In the Fig. 1 embodiment, there are two amplifiers (41,42). These amplifiers are bidirectional, and are thus able to amplify traffic signals passing in either direction therethrough. In the embodiment shown, the amplifiers (41,42) are doped fibre amplifiers, preferably erbium doped fibre amplifiers. In the Fig. 1 embodiment, there are two such amplifiers. First amplifier (41) is located between the second port of the first circulator (21) and the first fibre Bragg grating (31), whereas the second amplifier (42) is located between the second port of the last circulator (22) and the second fibre Bragg grating (32). As the amplifiers (41,42) are doped fibre amplifiers, it is necessary for them to be pumped. This is achieved by a pumping section (50). The pumping section comprises either one or two lasers (51,52) whose output is provided to one side of a fibre optic coupler (53). The advantage of providing two lasers is that redundancy is provided thereby and the system will still function in the event of the failure of one laser. The output from the laser or lasers is split by the coupler onto two output paths. One output path is coupled by means of a first further fibre optic coupler (54) to provide pumping light for amplifier (41), whereas the other output path is provided by means of a second further fibre optic coupler (55) to pump the second amplifier (42). The further couplers are preferably adapted so that all the pumping

light is transferred across the coupler to pump the amplifier, but that none of the traffic signals are transferred across the coupler for direction to the pumping section (50). In the arrangement shown, the couplers are provided between the amplifiers (41,42) and the adjacent circulators (21,22).

As can be seen, the circulators in Fig. 1 form a linear chain. Inclusion of the pumping section gives a ring structure, but it will be noted that no traffic signals travel along the pumping section part of this ring. It will be appreciated by the skilled man that similar linear chain arrangements with a first and a last three port circulator but with a plurality of four port circulators therebetween may be implemented in the case of branching units for use with further trunk fibres or branches.

TABLE 1

CHANNEL	WAVELENGTH	AMPLIFIED BY
Trunk 1 through	λ_2	41
Trunk 2 through	λ_1	42
Trunk 1 drop	λ_1	42
Trunk 2 drop	λ_2	42
Trunk 1 add	λ_1	41
Trunk 2 add	λ_2	41

As is shown in Table 1 above, each required routing for traffic signals between an input and an output achieved by the add/drop multiplexer (it is noted that in this arrangement there is no routing of the signals between the first and the second trunk fibre) is amplified, and that each of the amplifiers (41,42) amplifies a plurality of such routings. First amplifier

(41) amplies once signals passing directly along the first trunk, amplifies twice signals added to the first trunk from the branch input (3), and amplifies once signals added to the second trunk from the branch input (3). Second amplifier (42) amplifies once signals passing straight along the second trunk, amplifies once signals dropped from the first trunk to the branch output (13), and amplifies twice signals dropped from the second trunk to the branch output (13).

A similar arrangement achieving the same functionality is shown in Fig. 2. In this second embodiment, there are four circulators in a linear chain, and all of the circulators are three port circulators. At the pumping section and first and last circulator are as in the first embodiment, as are the amplifiers (41,42) and the first and second fibre Bragg grating (31,32). However, the second circulator (23) is now replaced by two midchain three port circulators (24,25) (termed here "midchain" circulators as they are in the middle rather than at the end, of the linear chain). For the first midchain circulator (24), the first port is connected to the first trunk input (24), the second port is connected to the first fibre Bragg grating (31), and the third port is connected to the first port of the second midchain circulator (25). The second port of the second midchain circulator (25) is connected to the second fibre Bragg grating (32) and the third port of this circulator (25) is connected to the second trunk output (12).

As can be seen, the functionality of this embodiment is the same as that of the first embodiment, and the same traffic signal routings are amplified the same number of times by the same amplifiers as before. Again, the arrangement can be expanded by adding further three port circulators (in pairs if symmetry is required in channels for inut and output). A combination of three and four port circulators could also be provided.

It will be appreciated that these arrangements will provide an effective add/drop

multiplexer arrangement suitable for use even when no amplification is required. In this event, pumping section (50) and couplers (54,55) are not required, and neither are amplifiers (41,42). The Fig. 1 embodiment in particular provides an especially low component count for a device of its functionality.

Provision of the amplifiers (41,42) within an add/drop multiplexer of this type is particularly advantageous, as it allows all traffic signal routings required to be amplified effectively with only two doped fibre amplifiers. This allows for particularly effective optimisation of design of an add/drop multiplexer combining reduction of component count and controllability of losses and gain.

CLAIMS

1. An add/drop multiplexer for use in a wavelength division multiplexed optical network, the add/drop multiplexer having a first trunk input for receiving traffic signals from a first part of a first trunk fibre, a second trunk input for receiving traffic signals from a first part of a second trunk fibre, a first trunk output for outputting traffic signals to a second part of the first trunk fibre, a second trunk output for outputting traffic signals to a second part of the second trunk fibre, a branch input for receiving traffic signals from a branch input fibre, and a branch output for outputting traffic signals to a branch output fibre;

the add/drop multiplexer comprising:

means of routing from the first trunk input to the branch output a first set of traffic signals at carrier wavelengths predetermined for transmission of signals from the first trunk fibre to a branch station and for routing from the second trunk input to the branch output a second set of traffic signals at carrier wavelengths predetermined for transmission of signals from the second trunk fibre to the branch station, and means for combining said first and second sets of traffic signals for output at the branch output;

means for separating traffic signals received at the branch input into a third set of traffic signals at carrier wavelengths predetermined for transmission of signals from the branch station to the first trunk fibre and a fourth set of

traffic signals at carrier wavelengths predetermined for transmission of signals from the branch station to the second trunk fibre, and means for routing the third set of traffic signals to the first trunk output and the fourth set of traffic signals to the second trunk output respectively; and

one or more amplifiers located on traffic signal paths determined by said routing means, such that said one or more amplifiers amplify each routing for traffic signals determined by said routing means and each of said one or more amplifiers is adapted to amplify traffic signals for a plurality of said routings.

2. Add/drop multiplexer as claimed in claim 1, wherein said one or more amplifiers are bidirectional amplifiers, and wherein for at least one of said one or more amplifiers traffic signal routings are arranged pass through said amplifier in opposite directions.

3. Add/drop multiplexer as claimed in claim 1 or claim 2, wherein said one or more amplifiers are doped fibre amplifiers, and wherein the add/drop multiplexer further comprises a pumping section for pumping of said doped fibre amplifiers.

4. Add/drop multiplexer as claimed in claim 3, wherein said pumping section comprises a first laser and a fibre optic coupler, wherein the output of the first laser is split into two output paths by said fibre optic coupler.

5. Add/drop multiplexer as claimed in claim 4, wherein said pumping section further comprises a second laser, wherein the second laser and the first laser are connected

to the same side of the fibre optic coupler so that light provided on each of the two output paths is a combination of light provided by the first laser and light provided by the second laser.

6. Add/drop multiplexer as claimed in any preceding claim, wherein the add/drop multiplexer comprises a plurality of optical circulators and a plurality of notch reflection filters.

7. Add/drop multiplexer as claimed in claim 6, wherein said notch reflection filters are fibre Bragg gratings.

8. Add/drop multiplexer as claimed in claim 6 or 7, wherein the plurality of optical circulators forms a linear chain.

9. Add/drop multiplexer as claimed in claim 8, wherein the first and last circulators in the chain are three port circulators.

10. Add/drop multiplexer as claimed in claim 9, wherein the first port of each of the first and last circulators is connected to a different input of the add/drop multiplexer, and wherein the third port of each of the first and last circulators is connected to a different output of the add/drop multiplexer, wherein the second port of each of the first and last circulators is connected to the adjacent circulator in the linear chain.

11. Add/drop multiplexer as claimed in claim 10, wherein one or more further circulators

in the linear chain are four port circulators, wherein a first port of each of said further circulators is connected to a different input of the add/drop multiplexer, a fourth port of each of said further circulators is connected to a different output of the add/drop multiplexer, and the second and third ports of each of said further circulators are connected to adjacent circulators in said linear chain.

12. Add/drop multiplexer as claimed in claim 10 or claim 11, wherein one or more further circulators in the linear chain are three port circulators, wherein for said further three port circulators either the first port of the further three port circulator is connected to an input of the add/drop multiplexer and the second and third ports of the further three port circulator are connected to adjacent circulators of the linear chain, or the third port of the further three port circulator is connected to an output of the add/drop multiplexer and the first and second ports of the further three port circulator are connected to adjacent circulators of the linear chain.

13. Add/drop multiplexer as claimed in any of claims 8 to 12, wherein a first set of notch reflection filters is provided between the first and a second circulator to reflect signals at a first set of one or more traffic signal wavelengths, and a second set of notch reflection filters is provided between the penultimate and the last circulator to reflect signals at a second set of one or more traffic signal wavelengths.

14. Add/drop multiplexer as claimed in any of claims 8 to 13, wherein said one or more amplifiers are located on the linear chain between the first and the last circulators.

15. Add/drop multiplexer as claimed in claim 14 where dependent on claim 13, wherein at least two amplifiers are provided, wherein one of said two amplifiers is located between the first circulator and the first set of notch reflection filters and the other of said two amplifiers is located between the second set of notch reflection filters and the last circulator.

16. Add/drop multiplexer as claimed in any of claims 8 to 15 where dependent on claim 3, wherein the output or outputs of the pumping section is or are coupled to the linear chain by one or more further fibre optic couplers.

17. Add/drop multiplexer as claimed in claim 16 where dependent on claim 15, wherein the pumping section has at least two outputs, wherein one of said two outputs is coupled to the linear chain adjacent to the first of said two amplifiers and the second of said two outputs is coupled to the linear chain adjacent to the second of said two amplifiers.

18. Add/drop multiplexer as claimed in claim 17, wherein the first of said pumping section outputs is coupled to the linear chain between the first circulator and the first amplifier, and the second of said pumping section outputs is coupled to the linear chain between the second amplifier and the last circulator.

19. Add/drop multiplexer as claimed in claim 11 or any of claims 13 to 18 where dependent on claim 11, wherein the linear chain consists of three circulators.

20. Add/drop multiplexer as claimed in claim 12 or any of claims 13 to 18 where dependent on claim 12, wherein the linear chain consists of four circulators, and wherein both the second and the third circulator in the chain are three port circulators.

21. Add/drop multiplexer as claimed in claim 20, wherein the first port of the second circulator has an input of the add/drop multiplexer connected thereto and the third port of the third circulator has an output of the add/drop multiplexer connected thereto.

22. An add/drop multiplexer for use in a wavelength division multiplexed optical network, the add/drop multiplexer having a plurality of inputs each for receiving traffic signals from a different fibre of the network and a plurality of outputs each for outputting traffic signals to a different fibre of the network, wherein the add/drop multiplexer comprises a plurality of optical circulators and a plurality of notch reflection filters wherein:

the plurality of optical circulators form a linear chain;

the first and last circulators in the chain are three port circulators, wherein the first port of each of the first and last circulators is connected to a different input of the add/drop multiplexer, and wherein the third port of each of the first and last circulators is connected to a different output of the add/drop multiplexer, wherein the second port of each of the first and last circulators is connected to the adjacent

circulator in the linear chain; and

one or more further circulators in the linear chain are four port circulators, wherein a first port of each of said further circulators is connected to a different input of the add/drop multiplexer, a fourth port of each of said further circulators is connected to a different output of the add/drop multiplexer, and the second and third ports of each of said further circulators are connected to adjacent circulators in said linear chain.

23. An add/drop circulator as claimed in claim 22, wherein a set of notch reflection filters is provided between one or more pairs of adjacent circulators to reflect signals at a set of one or more traffic signal wavelengths.

24. An add/drop circulator as claimed in claim 23, wherein the add/drop multiplexer comprises only one further circulator, and wherein:

the first port of the first circulator is connected to an input from a branch of the network;

the third port of the first circulator is connected to an output to a first trunk of the optical network;

the first port of the second circulator is connected to an input from the first trunk of the optical network;

the fourth port of the second circulator is connected to an output to a second trunk of the optical network;

the first port of the third circulator is connected to an input from the second trunk of the optical network;

the third port of the third circulator is connected to an output to a branch of the network; and

a first set of notch reflection filters is provided between the first and the second circulator to reflect signals at a first set of one or more traffic signal wavelengths, and a second set of notch reflection filters is provided between the second and the third circulator to reflect signals at a second set of one or more traffic signal wavelengths.

25. An add/drop multiplexer substantially as described herein with reference to Figures 1 and 2 of the accompanying drawings.

26. A branching unit for a wavelength division multiplexed optical network comprising an add/drop multiplexer as claimed in any of claims 1 to 25.

The Patent Office

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Application No:	GB 9702084.6	**Examiner:**	Stephen Brown
Claims searched:	22-24 & 26	**Date of search:**	18 December 1997

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4B (BKX, BK20T1)

Int Cl (Ed.6): H04B: 10/213, H04J: 14/02.

Other: Online WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0 638 837 A1 (CSELT) See figure 3	-
A, E	WO 97/06614 A1 (STC) See figure 22.	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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